Measurement of Net Ocean Surface Heat Flux during the ONR CBLAST Low Wind, Convective Regime Field Program using a New Ocean Surface Contact Sensor

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LONG-TERM GOALS

The long-term goal of our project is the complete development of a novel, surface-contact, wave-following multi-sensor float to simultaneously measure net ocean surface heat flux, solar irradiance and skin temperature. We envision multiple instruments deployed from small boats or drifting buoys in support of air-sea flux field experiments as well as long-term untended operation providing continuous measurements of heat flux and solar irradiance.

OBJECTIVES

Our one year ONR program focuses solely on *in-situ* data collection and analysis for CBLAST-Low (2003). The objectives of our research are: (1) to provide local net surface heat flux data using a novel measurement technique, which in conjunction with meteorological, turbulence and radiometric information can be used for improvement of heat flux parameterizations in calm and extremely low wind speed conditions, (2) to simultaneously measure skin/bulk water temperature difference and net surface heat flux data with high-temporal resolution at precisely the same location. This information would be valuable for improvement of existing coupled parameterizations which include the oceanic mixed layer, sea surface temperature and the atmospheric surface layer.

APPROACH

In the early 1990's, the Space Science & Engineering Center (SSEC) at the University of Wisconsin - Madison began development of an *in-situ* skin-layer ocean heat flux instrument (SOHFI) to measure net heat transfer between the atmosphere and ocean (Suomi, *et al.* 1996; Sromovsky, *et al.* 1999a, 1999b; Boyle, 1999, 2000). SOHFI measures the net surface heat flux by placement of a thin, commercially available flux plate (Ortolano,1983) within the aqueous thermal conductive sublayer.

The critical element is a light, wave-following, surface float containing two thin flux plates (Fig. 1). Each flux plate has a thermopile and a thermocouple bonded into a flexible mylar film sandwich. One plate has clear mylar outer layers; the other uses black dyed mylar. The difference in solar absorption properties allows solar irradiance to be distinguished from sensible and evaporative heat fluxes. Measured fluxes from each plate can be decomposed:

$$F_{clear} = F_{LS} - \alpha_c F_{solar} + F_{IR} \tag{1}$$

$$F_{black} = F_{LS} - \alpha_b F_{solar} + F_{IR} \tag{2}$$

where F_{clear}, F_{black} are flux plate values, F_{LS} represents the combined latent and sensible heat flux acting across the thermal sublayer, F_{solar} is solar flux, F_{IR} is the net infrared flux,

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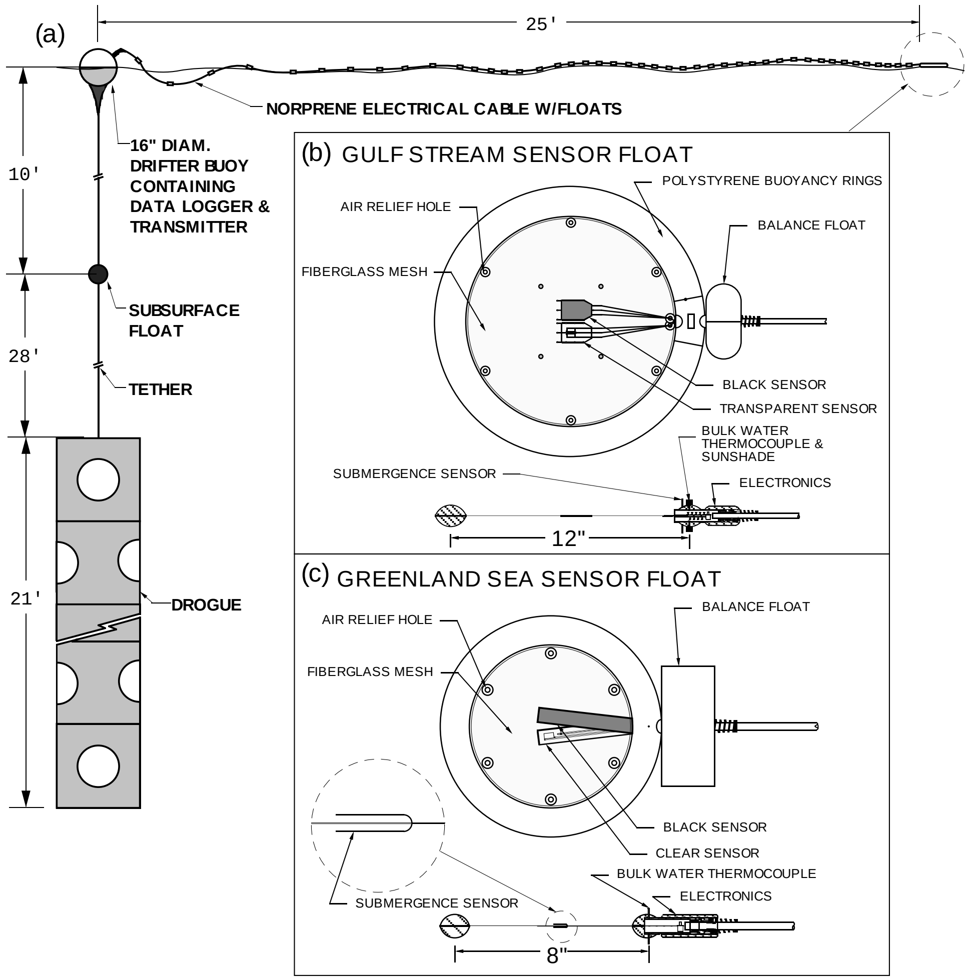

Figure 1: Ocean drifter configuration for field measurements: (a) Lagrangian drifter package with buoy and surface float, (b) detailed top view of sensor float used in early Gulf Stream deployment, and (c) detailed view of a revised sensor float design used in the Greenland Sea deployment.

and the α's are empirically determined solar response coefficients. In this model, nighttime fluxes measured by each flux plate are the same. During the day, the difference in flux plate signals is proportional to sea surface irradiance.

This project is lead by the PI, J. P. Boyle, Ph.D., with assistance from undergraduate students. Dr. W. P. Menzel, Chief Scientist, NOAA/NESDIS Office of Research & Applications, will participate as a partner and reviewer in data analysis and intrepretation. Dr. Menzel has a special interest in the SOHFI project and has extensive experience with sea surface temperature measurement using satellite observations.

WORK COMPLETED

A robust, recoverable drifting buoy (RDB01) was designed and built similar to that shown in the figure above. This new buoy includes a rechargeable battery, signal processing electronics, global positioning system unit, and a spread spectrum tranceiver for communication with

Table 1: Deployment Overview

Date (YDAY)	Duration (EDT)	$MSF^{\dagger}$ ($platform^{\ddagger}$)	WCSU Auxiliary Sensors
8-14-03 (226)	0645 - 0915	SN011(RDB01)	SST
—	0645 - 0915	SN010(BWB/V)	solar & long wave radiation
8-14-03 (226)	1700 - 2100	SN011(RDB01)	SST
—	1700 - 2100	SN010(BWB/V)	solar & long wave radiation
—	1700 - 2100	SN013(BME/V)	temp., humidity & wind
8-15-03 (227)	1300 - 1630	SN011(RDB01)	SST
—	1300 - 1630	SN013(BWB/V)	solar & long wave radiation
—	1300 - 1630	SN010(BME/V)	temp., humidity & wind
8-20-03 (232)	0925 - 1250	SN011(RDB01)	FV Nobska
8-21-03 (233)	0645 - 1415	SN011(RDB01)	FV Nobska
8-27-03 (239)	2200 - 0125	SN011(RDB01)	SST
—	2200 - 0125	SN010(BWB/V)	solar & long wave radiation
8-28-03 (240)	1530 - 1830	SN011(RDB01)	SST
—	1530 - 1830	SN010(BWB/V)	solar & long wave radiation
—	1530 - 1830	SN013(BME/V)	temp., humidity & wind
8-29-03 (241)	0045 - 0057*	SN011(RDB01)	SST

† MSF "multi-sensor float" only Greenland Sea design serial numbers: 010, 011, 013 used

‡ RDB01 "recoverable drifter buoy" freely drifting, similar to Fig. 1

‡ BWB "Big White Box", BME "Boat Met. Enclosure": onboard a tending vessel (V)

* SN011 run over and destroyed by FV Patricia Lynn – tending vessel

the deployment vessel or a land-based station.
During CBLAST-Low, three sensor floats were used – one attached to RDB01 and two tethered to an instrumented deployment/recovery vessel. Deployments consisted of a series of short-term, partially-tended observations in conjuction with the intensive operating period in August 2003. Instrumentation and deployments are summarized in Table 1 and Fig. 2.

RESULTS

Because the data collection period ended August 31, 2003, only preliminary results are available at this time. Fig 3 is a time series of a four hour period near sunset. The winds were light ($U_5 \simeq 2.5$ m/s); humidity was 85 – 90 %. Good correlation exists between clear and black flux plates and the cloud modulated solar flux. Nighttime flux plate values represent a net heat loss (turbulent transport plus infrared cooling). The daytime fluxes are depressed by solar absorption – the difference between clear and black flux plate signals is proportional to solar irradiance. The increased noise in the flux signal after sunset may be associated with increased convective motion due to cooling at the ocean interface – as indicated in the lowest plot.

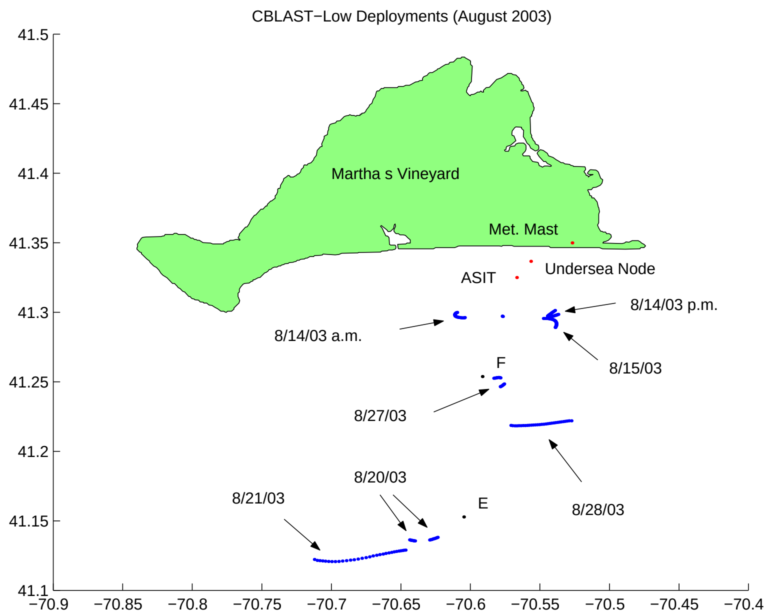

Figure 2: Deployment Overview: the Air-Sea Interaction Tower (ASIT), Meteorological (Met.) Mast and Underwater Node are associated with the Martha's Vineyard Coastal Observatory (MVCO). Moored buoys at locations E & F include surface heat flux measurement instrumentation. Blue dots represent drifting buoy tracks.

IMPACT/APPLICATIONS

The net heat flux from the ocean to the atmosphere is the sum of sensible, latent and thermal radiative fluxes minus the short wavelength solar energy absorbed in the upper ocean. Traditionally, each of these individual contributions is measured separately, and in general, each measurement employs a model or includes empirical parameterizations in the measurement scheme. Use of multiple instruments is expensive and time consuming; in addition, models can lead to inaccuracies.

Our heat flux measurement is direct. There is no need to measure auxiliary variables such as wind speed or turbulence parameters. There is no need for models or parameterizations. In principle, our measurement technique could yield increased accuracy over a wide range of environmental conditions and could allow heat flux measurement in regions with complex three dimensional airflow and highly variable tidal and sea state conditions – where current parameterizations are difficult to apply. In particular, our measurement technique is uniquely capable of air-sea heat flux measurement in calm and extremely low wind conditions. It can readily and inexpensively provide data to assess the validity of conventional physics-based surface heat flux and skin/bulk temperature difference parameterizations in this regime.

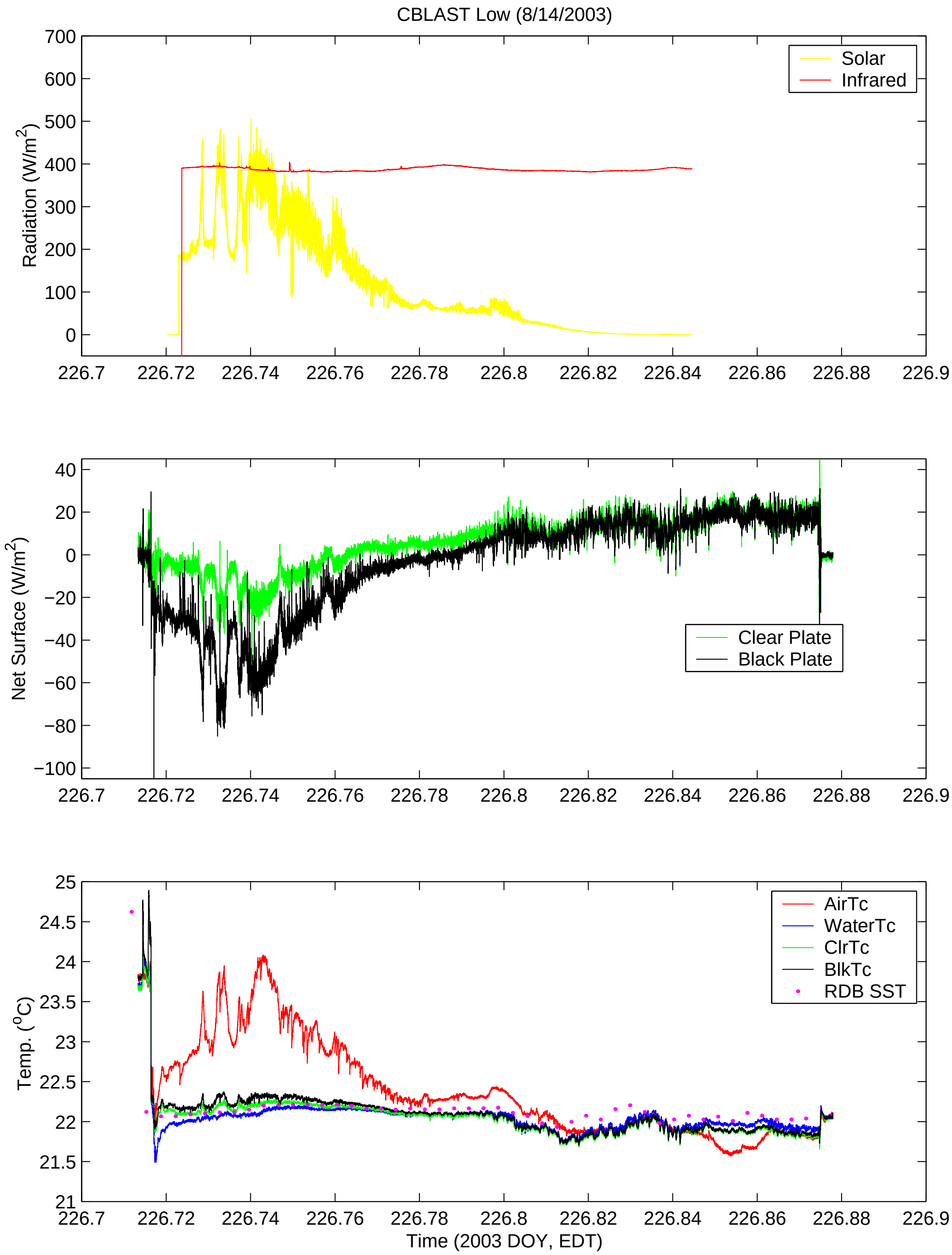

Figure 3: Time Series of radiation, net surface heat flux and ocean temperature measurements near sunset. The upper plot shows shipboard measured downwelling radiant fluxes. The lower two plots are from a freely drifting sensor float. The middle plot shows the raw flux signal – no calibration factors or temperature corrections have been performed. In the lower plot, it is apparent the air temperature sensor is not shielded. This feature allows more sensitive detection of the direct solar beam for diagnostic purposes and a relatively fast indication of large submergence events.

RELATED PROJECTS

The PI, J.P. Boyle, Ph.D., also currently has a National Sea Grant Organization Technology grant to continue development of the multi-sensor float. Funding for the Boat Meteorological Enclosure (BME) and associated meteorological instrumentation was made available through "seed" funds from Connectict Sea Grant and the University of Bridgeport.

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